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Analyzing weak lensing of the cosmic microwave background using the likelihood function

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September 24, 2002

abstract Future experiments will produce high-resolution temperature maps of the cosmic microwave background (CMB) and are expected to reveal the signature of gravitational lensing by intervening large-scale structures. We construct all-sky maximum-likelihood estimators that use the lensing effect to estimate the projected density (convergence) of these structures, its power spectrum, and cross-correlation with other observables. This contrasts with earlier quadratic-estimator approaches that Taylor-expanded the observed CMB temperature to linear order in the lensing deflection angle; these approaches gave estimators for the temperature-convergence correlation in terms of the CMB three-point correlation function and for the convergence power spectrum in terms of the CMB four-point correlation function, which can be biased and non-optimal due to terms beyond the linear order. We show that for sufficiently weak lensing, the maximum-likelihood estimator reduces to the computationally less demanding quadratic estimator. The maximum likelihood and quadratic approaches are compared by evaluating the root-mean-square (RMS) error and bias in the reconstructed convergence map in a numerical simulation; it is found that both the RMS errors and bias are of order 1 percent for the case of Planck and of order 10–20 percent for a 1 arcminute beam experiment. We conclude that for recovering lensing information from temperature data acquired by these experiments, the quadratic estimator is close to optimal, but further work will be required to determine whether this is also the case for lensing of the CMB polarization field.